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TERRAIN INFORMATION EXTRACTION SYSTEM SUPPORT TO PLANNING

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ABSTRACT

Knowledge of the terrain is essential to the planning of military operations. Increasingly terrain data is needed in digital form for use in automated analyses and mission rehearsal/simulation. Although the Defense Mapping Agency generates such data, there are gaps in coverage and the data soon becomes outdated. Consequently, the Army is developing a Terrain Information Extraction System (TIES) to supplement DMA production. This paper describes the TIES, an all digital photogrammetric system for extracting terrain data from recent imagery. The configuration and functions of the system are enumerated. Plans for future improvements to the system are reported and how it could be used in supporting crisis operations is delineated.

THE NEED FOR EASILY ACCESSIBLE INFORMATION ABOUT THE TERRAIN

From the beginning of warfare, knowledge of the terrain has been important to the combatants. The side which best took advantage of the terrain has usually been successful. For many years, the topographic map has been the standard for providing terrain data to the military. It will continue to be useful for the foreseeable future, but it has its limitations. Information conveyed on it about terrain features is limited because it must all be provided by symbols. Recently, maps have been supplemented with terrain overlays which provide more detailed information about terrain features. All of this information is difficult to assimilate from hardcopy sources. However, if the data are compiled in digital form more information can be provided, and it can be accessed easily. The switch to digital data has been fueled by the development of new technologies as well. Systems to visualize terrain electronically from different viewpoints to provide better appreciation of terrain than can be obtained from contour data are becoming more common. Also more and more automated weapons and command and control systems are being developed. These systems must have digital terrain data to function.

SOURCES OF DATA

The Defense Mapping Agency (DMA) is the primary supplier of terrain data for the military. DMA continues to supply standard hardcopy map products, and in recent years has begun producing digital products to meet military needs. Chart I lists some of

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these products. These are the standard source of digital terrain data for the military. However, there are situations when DMA products may not meet the needs of military planners. These situations are enumerated on Chart II. To deal with situations when DMA data are not available or don't provide sufficient detail, we at U.S. Army Engineer Topographic Laboratories (USAETL) are developing an Army capability for extracting terrain data from imagery and existing map sources.

THE TERRAIN INFORMATION EXTRACTION SYSTEM

The system being developed is called the Terrain Information Extraction System (TIES). An experimental prototype of the TIES was completed this year. It is the first low cost, end to end digital, image-based mapping system in DOD. TIES did not have to be an all digital system in order to produce digital data; however, the choice of the digital approach offers several advantages. The system requires few optical/mechanical components and is, therefore, more reliable and less susceptible to wear and shock damage. It also has the flexibility to process imagery from a variety of sensors including those with digital outputs. The most important advantage is that this approach allows the computer to interact directly with the imagery. This allows the system to run both manual and automated processes and permits the future addition of more automated processes. The digital processing approach also has a disadvantage. Digital image files can be very large and become a problem to store. A photo is a very efficient storage medium. TIES is well equipped to handle imagery whether it is received in digital or hardcopy form.

The manner in which TIES operates is illustrated on Chart III. The primary input for the system is imagery from a sensor flown in an aircraft or satellite. The imagery may be brought back by the aircraft in hardcopy format or transmitted to a ground station directly from the aerial vehicle in digital format. If the imagery is already in digital form, it may be used directly in the Digital Stereo Photogrammetric Workstation which we refer to as the DSPW. Hardcopy imagery must first be digitized by the Image Digitizing System. The actual data extraction is done on the DSPW which provides capabilities to update existing files of digital terrain data, such as DMA Interim Terrain Data (ITD), to supplement DMA data with more detail in limited areas, and to generate terrain data from scratch. A geographic information system incorporated in TIES is the interface with other suppliers of and customers for terrain data and the repository of files created or updated in the DSPW.

Chart IV is a picture of the Image Digitizing System or IDS. It was built for USAETL by Intergraph Corporation which subcontracted to Zeiss of Germany for the mechanical base of the flat bed scanner. It is one stage of a precise analytical

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stereoplotter, and, consequently, it moves the photo stage during scanning with high metric accuracy and repeatability. Intergraph installed the CCD camera which allows digitizing with resolutions from 7.5 to 120 μm . Intergraph also included three color filters in the illumination system which will allow color imagery to be scanned in its component colors. Scanning in this manner does, however, create three times as much digital data. A 10 x 10 inch photo can be scanned at 15 μm in 10 minutes. Its scanning speed allows the IDS to support multiple workstations and makes storage of imagery in hardcopy practical. Also, the IDS can scan patches of a photo when the user doesn't need to work with the entire photo, and relate these patches to the coordinate system established by the fiducials or other reference marks on the photo.

After placing the imagery on the photo stage, the operator controls the process from the Intergraph Interpro workstation. He or she can verify scanned files and can use available software tools to control the quality of the output.

Chart V is a picture of the DSPW which was built for USAETL by General Dynamics. It is based on a standard commercial Sun Workstation and includes a Vitec image processor and a Tektronix stereo display on which a three-dimensional model of terrain can be viewed. The operator selects appropriate system software using the left screen and interacts with the image stereo model on the right screen.

Applications software available on the DSPW includes capabilities to relate the imagery to a ground coordinate system, measure heights and distances, extract elevations automatically and edit them, delineate or edit terrain features, and generate orthophotos. An orthophoto is a photo in which all distortions have been removed so that any measurements made on it are accurate.

The only automated processes on the DSPW are orthophoto generation and the extraction of elevation data by automated correlation (image matching). Although one of the best automated correlation schemes is used, not all of the elevations derived will be correct and interactive editing is generally needed to correct those.

Action has been started to add an Image Perspective Transformation capability to the DSPW. While this will allow the generation of perspective scenes at a fairly slow rate, it is intended primarily to allow the operator to generate and edit data for use on more sophisticated simulators. This software will streamline construction of wireframe building models and the incorporation of additional images for use in terrain visualization.

TIES provides state-of-the-art capabilities for mapping terrain, however, it is highly interactive. A human operator does most of the feature identification, measurement and delineation. Our future plans are to use the prototype TIES as a test bed for development of greater automation through insertion of expert system and feature extraction software modules. In the meantime, generation of data on a TIES-like system will be relatively slow and its use in support of military planning will have to be carefully planned.

STAGED SUPPORT TO MILITARY PLANNING

After determining what existing data, digital or hardcopy, and imagery was available to meet the request, an organization using TIES type system could offer the requesting organization options for meeting its needs. The decision on which products to provide first would involve trade-offs between the system's capabilities and the user's needs.

Rectified imagery is the first product which such a system could produce. This imagery would be somewhat easier to interpret than the raw imagery, but should only be considered for use if no other product is available or it could be used to supplement a badly outdated map. Measurements or coordinates extracted from this imagery could be expected to be incorrect and the user could easily fail to recognize or misinterpret features shown on it.

The next product to be generated would vary with the situation. If DMA digital data, such as DTED and ITD, for the area were available, it could be compared with the new imagery and quickly updated as necessary. Chart VI is an example of how ITD is brought into a stereo model in that process. If no DMA data were available or if it lacked sufficient detail, generation of elevation data for the area would begin immediately.

Once the elevations were completed, orthophotos could be generated and given to users in the field. Chart VII is an example of an orthophoto produced by TIES. Although it looks just like any other photo, each small picture element has been moved to its true horizontal position as determined from the math models constructed in the system. Orthophotos would be most useful to elements which needed them for navigation. Until further work could be done to add annotation to the orthophotos, interpretation of terrain features would be up to the user. A unit with simulators for visualizing terrain or rehearsing missions might prefer instead to have system resources used to generate wireframe models of buildings and merge imagery for use in those activities.

If no existing digital feature data such as ITD were available, TIES resources would next be devoted to compiling feature data for the area of interest. The DSPW operator, more experienced in

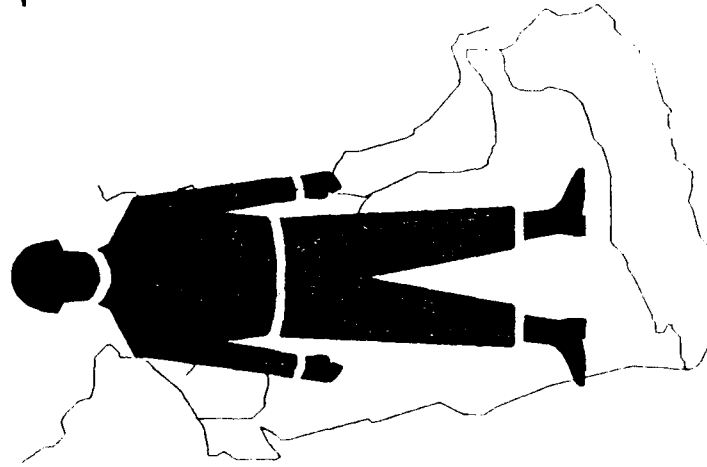
photo interpretation, will now be interpreting terrain features rather than the product user. This will make the end product easier to use. The operator can record multiple attributes for each feature as he or she delineates it. Extraction of features could continue until all features of interest to the user are compiled or stopped at any intermediate point. A complete compilation could substitute for ITD and provide the basis for constructing large scale line maps. Subsets could be taken off during the process to be used in simulations or overprinted on orthophotos. More detailed compilations of limited areas could be completed to support urban warfare or special missions.

SUMMARY

Unfortunately, TIES technology was not mature enough to contribute significantly to Operation Desert Storm. Though not fully tested, the technology is being spun off to some pilot production operations. In any future conflict, it should be capable of supplying digital terrain to meet some mission planning needs. The data it produces will support target analysis, navigation, mission planning, mission rehearsal and training. TIES technology is the basis for reliable and flexible systems capable of producing data in standard product formats, such as DTED and ITD. Such systems may be even more valuable for producing custom products, such as closely spaced grids of elevations and wireframe models of buildings to support terrain visualization systems. Ultimately, systems based on TIES are intended to be located in forward areas where they will be under control of the field commander and can, therefore, respond readily to priority needs. The system has been designed to model several sensors which were expected to be the most likely data sources. As other potential sources are identified, math models to process them can be added to the system. In the more distant future, the system will become more responsive as additional extraction processes are incorporated.

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- MC&G Video Discs

Elevation - Digital Terrain Elevation Data

Feature - Digital Feature Analysis Data
- Interim Terrain Data

Non-Standard MC&G Products



Used When
Defense Mapping Agency
MC&G Products
Don't Meet Requirements

- No Area Coverage
- Area Coverage Outdated
- Scale Inappropriate
- Product Inappropriate
- Supplemental Information Needed

TIES OPERATIONS

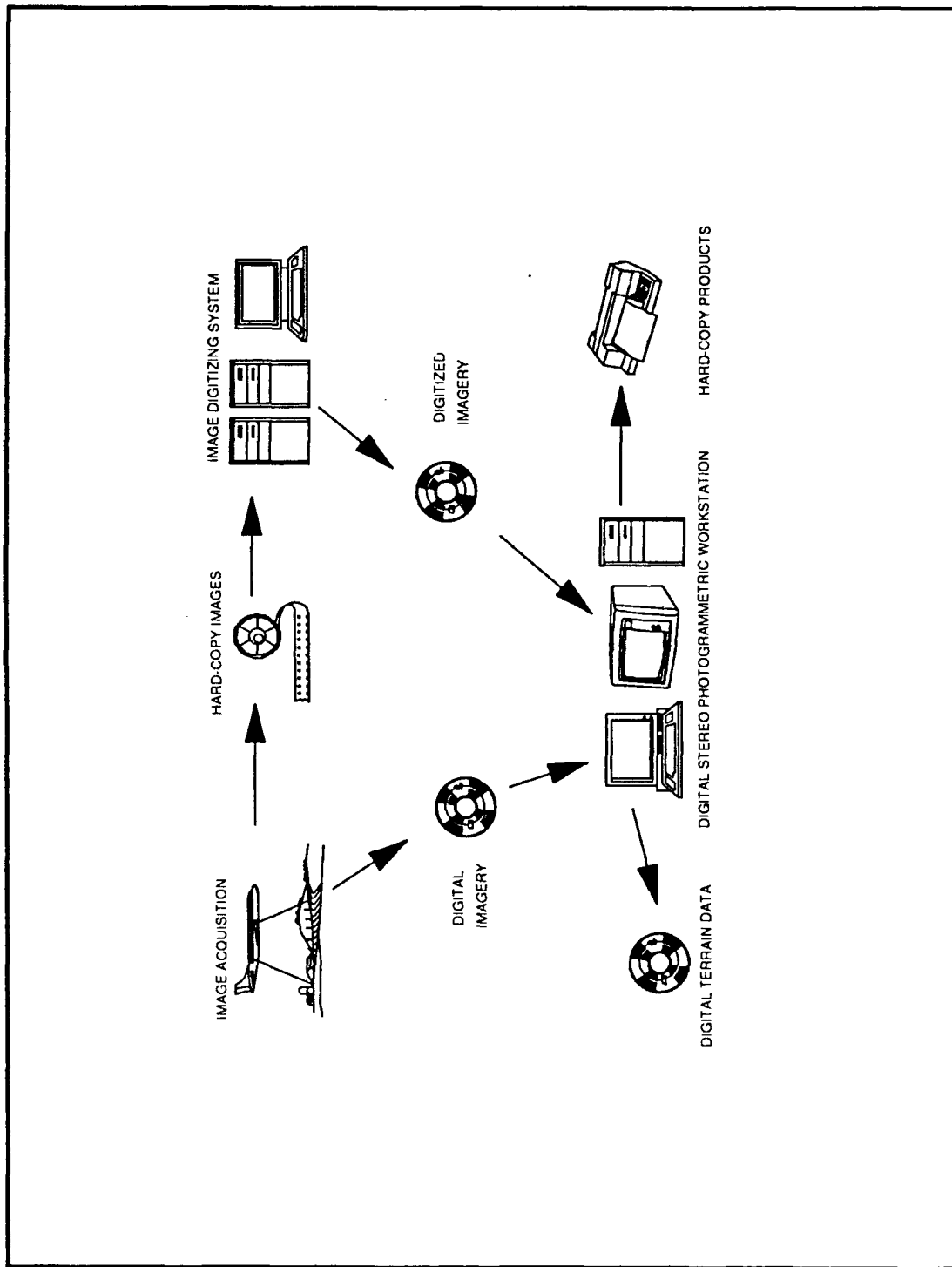


CHART III



IMAGE DIGITIZING SYSTEM (IDS)



CHART IV



DIGITAL STEREO PHOTOGRAMMETRIC WORKSTATION (DSPW)



CHART V



CHART VI - INTERIM TERRAIN DATA OVERLAID IN STEREO MODEL

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CHART V. ORTHOPHOTO PHOTOGRAPHY